Technical Memorandum

McSorley Creek Pocket Estuary Restoration Project

Analysis of Shoreline Geomorphic Processes

Purpose Statement

Coast & Harbor Engineering (CHE), a Division of Hatch Mott MacDonald, has prepared this technical memorandum for Confluence Environmental in order to summarize Task 200 analysis of shoreline geomorphology, sediment characteristics, sediment sources, wave energy and direction, and dominant littoral drift for the McSorley Creek Pocket Estuary Restoration Project at Saltwater State Park. This technical memorandum represents the first step to assess the potential for additional shoreline enhancements and softer protection mechanisms that would further enhance environmental benefits of the project as a whole, while maintaining important historical structures and options for enhancing low-impact recreational activities. Project objectives include removal of fill material to restore natural ecosystem processes in the intertidal zone, removal or replacement of shoreline armoring, restoration of the stream channel, enhancement of low-impact recreation opportunities, and evaluation of the cost-benefit of infrastructure relocation.

Summarized herein are analysis, data collected during field visits, and plots of potential sea level rise impacts for three sea level rise scenarios as required per the Scope of Work. Information contained in the memorandum will be used as the basis for performing additional analysis required for feasibility evaluations and preliminary design in subsequent tasks. The information in this technical memorandum is organized according to the tasks outlined in the project scope of work. Appendices A through E provide supplemental information and figures.

TABLE OF CONTENTS

Purpose Statement 1
1. Introduction 4
2. Review of Existing Information and Reference Data (Task 205) 4
3. Shoreline Geomorphic Processes Assessment (Task 204) 7
   3.1. Tidal Datums 7
   3.2. Historic Site Conditions and Shoreline Change 7
   3.3. Sediment Characterization 9
   3.4. Suitable Forage Fish Substrate 13
   3.5. Existing Rock and Fill 13
   3.6. Littoral Drift 14
   3.7. Coastal Processes Discussion 16
4. Evaluation of Predicted Climate Change Impacts (Task 206) 18
5. Summary of Key Findings 19
   5.1. Data 19
   5.2. Shoreline Modifications 19
   5.3. Shoreline Processes 19
   5.4. Sea-Level Rise 20
6. References 20

Appendix A – Historical Charts and Maps (T-Sheet, 1936, 2012)
Appendix B – Surface Sediment Photos
Appendix C – Grain Size Analysis (From Shannon & Wilson)
Appendix D – Wave Modeling (Domain, 2-Year Results from North and South)
Appendix E – Sea Level Rise Plots

FIGURES

Figure 1. Wind rose (left panel) and station location (right panel). Project site indicated by red square. 6
Figure 2. McSorley Creek tidal datum table for location shown in green on right. Existing NOAA tide stations shown by red pins 7
Figure 4. Shoreline position (yellow and white) and creek alignment (light blue and dark blue) in 1936 and 2015, respectively 9
Figure 5. Plot of sediment survey photo points 10
Figure 6. Variable sediment distribution on beach profile at South Shoreline (facing east) 12
Figure 7. Puget Sound Coastal Atlas littoral drift and coastal landforms 15
Figure 8. Coastal process summary and field indicators 17
Figure 9. Annual maximum high tide (NOAA Station ID: 9447130) 18

TABLES

Table 1. Topographic and Bathymetric Data Sources 4
Table 2. Two-Year Return Period Wind-Storm Wave Model Results 16

1. Introduction

This technical memorandum provides information about historical and existing site conditions at Saltwater State Park, and is intended to summarize shoreline geomorphic processes to a level suitable for evaluation of potential restoration actions in Task 400, Conceptual Design Evaluation. The information contained herein is preliminary; detailed modeling, analysis, and design will be performed in subsequent tasks.

2. Review of Existing Information and Reference Data (Task 205)

In order to characterize the project site, CHE has developed a project database which contains topography, bathymetry, aerial photographs, meteorology, and other miscellaneous data received from King County (County), as well as that obtained from other public sources. Project data and sources are described in the following sub-sections.

Table 1. Topographic and Bathymetric Data Sources

Data Source	Name	Comments
Topographic Data		
King County	City of Seattle – Seattle Public Utilities Survey: Conducted 2011	None
King County	Lidar: Bare Earth Ground Surface	No issues with topography, see comments on bathymetry
King County	ah_dlmkc.asc	Last-return Lidar (includes buildings). Not used.
King County	ah_dgmkc.asc	Bare earth ground surface. Data set to be used. No issues with topography, see comments on bathymetry.
King County	ah_dsmkc.asc	First-return Lidar. Not used.
Alliance-1	Project Base map. Survey conducted Aug 11, 2015	None
Bathymetric Data		
NOAA Hydrographic Survey	2008 multi-beam survey	None
King County	ah_dgmkc.asc	All ground elevation data in area of McSorley Creek delta were approximately 10’ MLLW and did not match elevations taken in the field. Elevations were likely associated to water surface elevation during Lidar collection. CHE replaced erroneous data with USACE blue-green Lidar for use in the project basemap.
Puget Sound Lidar Consortium (PSLC)	United States Army Corps of Engineers (USACE) Blue-Green Lidar, conducted in 2004	None

Data Source	Name	Comments
GIS Data		
King County	bathymetry2ft	Elevation Data. Superseded by Lidar and survey data.
King County	erosionSW	Ok. Identify sensitive erosion areas
King County	FLOODPLAINsw	Ok. 100-year floodplain
King County	forectconnSW	Forect connect
King County	landslideNW	Landslide hazard
King County	NWI_SW	National Wetlands Inventory
King County	Surfgeo1	Surface Geology
King County	T_line	1876 T-sheet map lines
King County	T_poly	1876 T-sheet map polygons
King County	UuwSoilsSW	Soils
Flood Map		
King County	King_County_Workmap_2011-12-22_PLATE 14.pdf	Flood Map including Saltwater State Park. Puget Sound Coastal Flood Hazard Work Maps King County, Washington. Ok. Draft. Elevation data collected in 2010.
Project As-built Drawings		
King County	C6560039.tif	Plan view of Park (1982)
King County	C6560049.tif	Park Boundary Survey and Culture Location (1969)
King County	C6560066.tif	Preliminary Construction Drawings (1952). Includes quantities estimate.
King County	C6560067.tif	Park Construction Details (1952). Includes cross section of bluff excavation and stream channel.
King County	C6560070.tif	Survey of the Beach, Picnic, and Parking Areas (1952). Appears to be post-construction survey.
S160-57 1A-Master Plan 1935	S160-57 1A-Master Plan 1935	Master Development Plan Saltwater State Park. No indications that the 1935 Master plan was implemented

Wind data are needed in order to evaluate wind-wave conditions at the project site. Long-term wind data records representative of overwater winds are relatively rare in central Puget Sound. Two sources of wind data were collected and evaluated. First, wind data from 1984 to 2014 were obtained from the National Oceanic and Atmospheric Administration (NOAA) wind station WPOW1 at West Point in Seattle, WA. Second, data at the more proximate Point Robinson Coast Guard Station (AWS 742075) were obtained from 1975 to 1990.

Though more distant from the project site, analysis indicates that West Point wind data are more recent, complete, high quality, and provide a long duration of observations reported on an hourly basis. Whereas the Point Robinson data are more local to the project site, the wind record is sporadic (typically five measurements per day) and the data record has significant gaps and quality issues. Therefore, the West Point winds are considered to be the best available data. The wind rose for West Point Station is shown in the top panel of Figure 1, and indicates northern and southern winds dominate. The figure indicates that typically the strongest winds are expected out of the south. The wind rose for the Point Robinson station is provided in the bottom panel of Figure 1 for comparison. The station exhibits similar trends to West Point, with a slight difference in wind direction from the north due to local topography and a relatively narrow band of wind directions, compared to West Point. In preliminary design, overlapping data between to the two stations (1984 to 1990) will be analyzed during known storm conditions to evaluate if local adjustments to the wind data at West Point are needed.

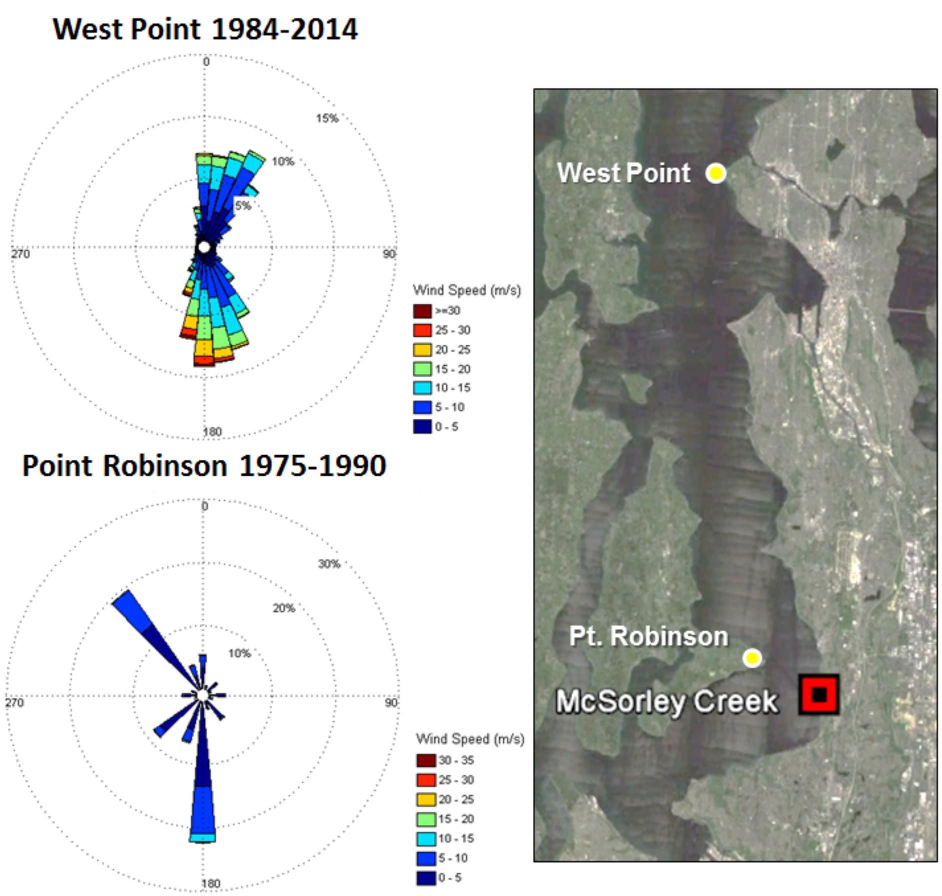

Figure 1. Wind rose (left panel) and station location (right panel). Project site indicated by red square.

3. Shoreline Geomorphic Processes Assessment (Task 204)

The following section describes shoreline geomorphology including the beach profile, sediment character, sediment sources, wave energy and direction, and dominant littoral drift.

3.1. Tidal Datums

No permanent tide station is located at Saltwater Sate Park; therefore, CHE developed tidal datums for the site using the NOAA tool, VDatum. VDatum is publically available software that interpolates site tidal datums from nearby tide stations with established tidal datum relationships. The resulting tidal datum table is shown in Figure 2. The figure provides tidal datums relative to two vertical references systems: Mean Lower Low Water (MLLW) and NAVD88 (project datum).

King County

McSorley Creek SP

Tidal & Vertical Datum Relationships for McSorley Creek, WA[1]

	MLLW DATUM (feet)	NAVD88 DATUM (feet)
Mean Higher High Water (MHHW)	11.72	9.20
Mean High Water (MHW)	10.84	8.32
Mean Sea Level (MSL)	6.85	4.33
Mean Tide Level (MTL)	6.85	4.33
National Geodetic Vertical Datum of 1929	6.02	3.50
Mean Low Water (MLW)	2.86	0.34
North American Vertical Datum of 1988[2]	2.52	0.00
Mean Lower Low Water (MLLW)	0.00	-2.52

Notes:

[1] Tidal datum relationships per NOAA Vdatum software at project site [UTM: 550925.0 m E, 5246787.0 m N, Zone 10]

[2] To convert an elvation from MLLW to NAVD88 Datum, subtract 2.52'

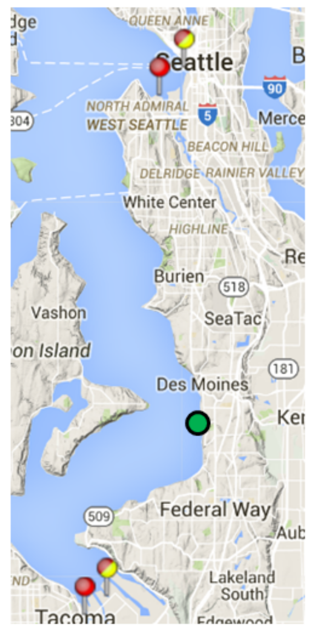

Figure 2. McSorley Creek tidal datum table for location shown in green on right. Existing NOAA tide stations shown by red pins.

3.2. Historic Site Conditions and Shoreline Change

The following summarizes key information gleaned from County provided data and photographs. It is noted that some distortions are present in the 1936 aerial photograph and that the quality of the photo makes distinguishing site features somewhat subjective. Therefore shoreline positions and creek locations are approximate, and may vary by ± 20 feet. Figure 3 provides a project feature definition keymap. Shoreline position and creek alignment in 1936 and 2015 is shown in Figure 4.

- 1876. T-Sheet depicts a creek entering Puget Sound via an estuary wetland complex. A bluff was located to the north of the creek mouth.

- 1926. The park was opened.
- 1936. From the available aerial photographs, the site shorelines and creek alignment appear in natural condition. Parking lots and footbridges are evident, as are buildings. The bluff was still active as a sediment source in 1936.
- 1944. Low resolution aerial photo available. Creek delta is visible, but unable to determine if shoreline and creek appear to be in natural condition.
- 1952. Per State Parks construction drawings (S-160-8-1, Estimate of Quantities) the major modifications to the shoreline occurred. As depicted in the construction drawings, the footprint and location of the armor rock is the same as that present today, and also included armor rock south of the creek mouth. Per the drawings, the sloping revetment was planned using 8,180 tons of Class B riprap. Bottom elevation of the placed riprap revetment ranged from approximately 1.2 feet NAVD88 to 4.4 feet NAVD88. Approximately 700 CY of Class A riprap were placed to realign and harden the creek channel. The shoreline was moved west by approximately 180 feet at the location of the new creek mouth.
- 1952. Per State Parks construction drawings, major bluff excavation occurred near the existing road in order to re-route the creek mouth to the north at its present location. The bluff toe was shifted approximately 80 feet north. Excavated bluff material was used as fill behind the riprap revetment. The creek was rerouted and the mouth was moved approximately175 feet to the north, to its present position and the toe of the excavated bluff.
- 1952 to Present. The creek delta has migrated north with the creek and the beach south of the creek has accreted. The creek continues to deliver sediment to the nearshore, and sediment is supplied from updrift sources as well as from the relic delta deposits. Approximately 6 feet of accretion has occurred at the toe of the rock revetment placed near the creek mouth, due at least in part to the migration of the creek delta. Approximately 600 feet north of the creek mouth, outside the top elevation of the delta, approximately 2.5 feet of accretion has occurred at the toe of the rock revetment.

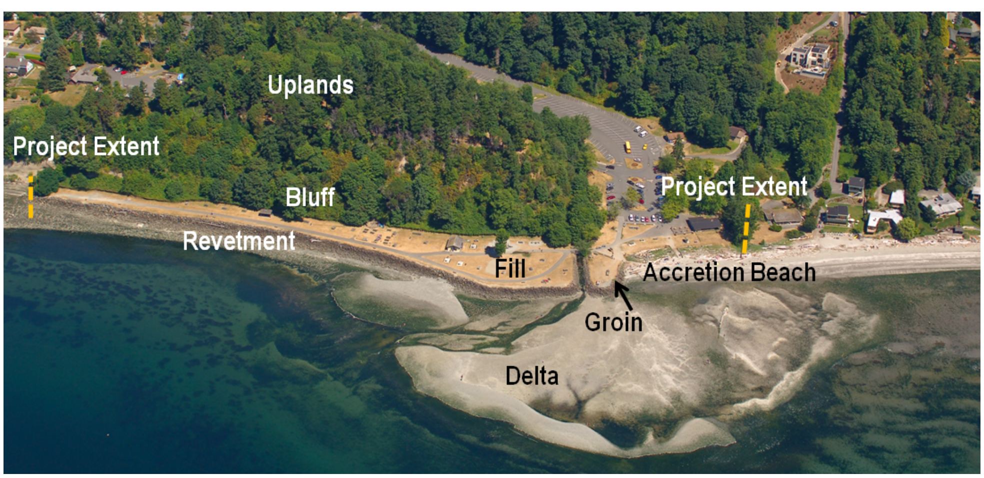

Figure 3. Project feature definition keymap

Figure 4. Shoreline position (yellow and white) and creek alignment (light blue and dark blue) in 1936 and 2015, respectively

3.3. Sediment Characterization

CHE conducted a site visit at low tide on the morning of August 11, 2015 to observe surface sediment physical characteristics throughout the project site. Sediment grain size, type, and distribution varies widely across the project site, but can be generally categorized into three distinct areas, based upon surface sediment characteristics: modified intertidal area fronting the riprap revetment shoreline (north shoreline); beach located south of the creek (south shoreline); and creek delta that fronts portions of the north and south shorelines and creek mouth riprap and groin (delta). Figure 5 provides a key map of surface sediment survey photo points that were collected during the site visit. Photos for each surface sediment point are included in Appendix A for reference. Grain size analysis for collected sediment samples (red color in Figure 5) are provided in Appendix B. Chemical characterization was not performed.

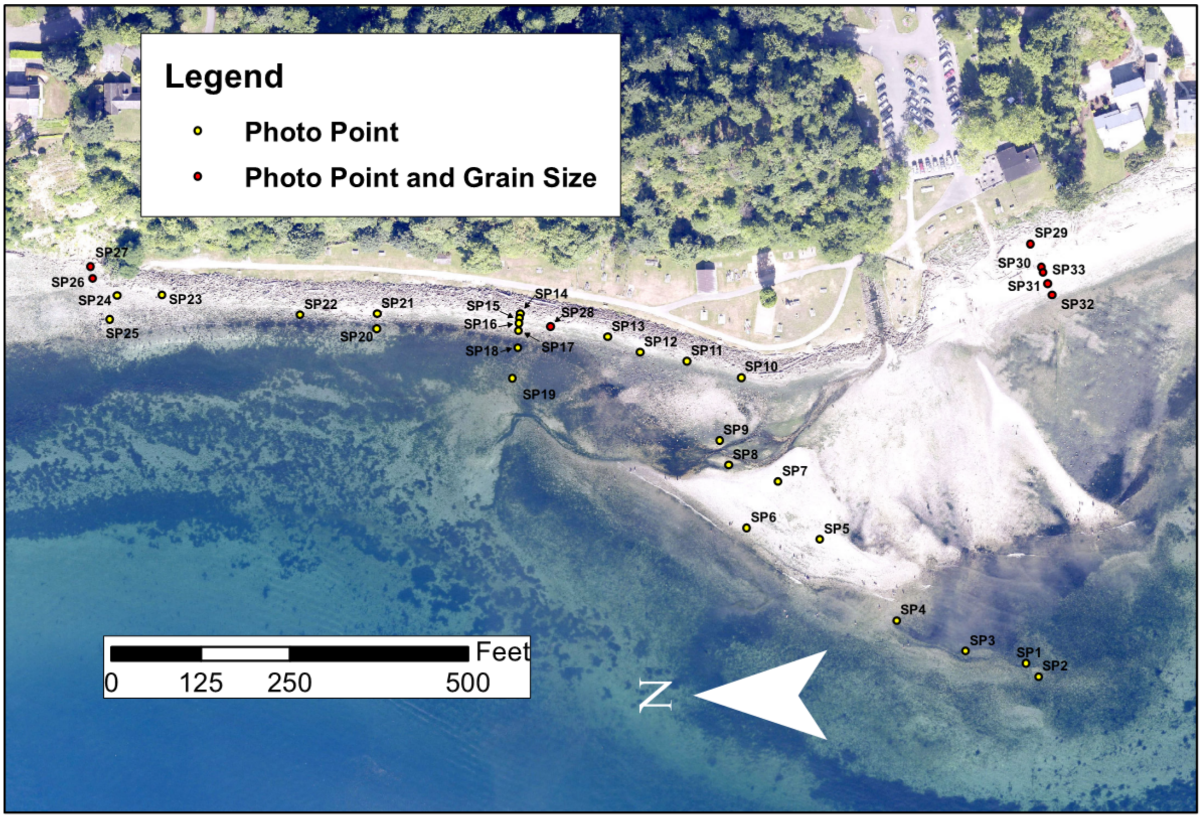

Figure 5. Plot of sediment survey photo points

3.3.1. North Shoreline Area

This portion of the project site, located north of the creek mouth, is heavily armored with a riprap revetment that extends from the upper intertidal zone down to an elevation that varies from about 2.0 feet NAVD88 at the north end of the project site to about to 6.0 feet NAVD88 near to the creek mouth. The presence of the delta generally results in less exposure of the riprap near the creek mouth. Based upon site observations and review of 1952 construction documents, the riprap likely extends below the interface with the surface sediments along the entire length of shoreline. It is expected that the riprap may extend about 4 feet below the surface near the creek mouth and approximately 1 to 2 feet below the surface north of the creek mouth and away from the delta area. Depths could be corroborated using hand probing, but may require permits to remove soil below the OHWM. Small riprap, typically smaller than 1 foot mean diameter, is scattered on the intertidal beach seaward of the riprap revetment. The sediment intermixed with the scattered riprap varies greatly in size and shape, but north of the delta is typified by gravel/cobble mixed with sand, as depicted in Sediment Point 15. Near the riprap revetment, scattered rounded to sub-rounded rock is prevalent. Waves can approach the north end of the riprap revetment from relatively deep water and more directly from both the northwest and the southwest; thus, leading to higher wave energy reaching this intertidal area than near the creek mouth. Sediment appeared finer at the northern extent of the north shoreline area, near the existing feeder bluffs and the intact beaches. However, it was noted that coarse cobble and gravel in the lower intertidal zone extend north, well beyond the project limits. This indicates a natural source of material in the adjacent bluffs.

3.3.2. South Shoreline Area

This portion of the project site, located south of the creek mouth, is armored along its northern boundary at the creek mouth groin and at a concrete stair access point. The 1952 construction drawings also indicate armor placed in the area of what is now the backshore berm. Confirmation of rock would require excavation as none is present at the surface due to beach accretion and vegetation growth. The beach in this area is a mixed sand-gravel beach, composed primarily of gravelly sand in the upper foreshore, with the percentage of gravel increasing lower on the beach face. Figure 6 illustrates the variable grain size distribution on the South Shoreline beach; grain size analysis plots are provided in Appendix C. The beach consists of a complete foreshore (slope 9H:1V) and mostly intact backshore that experiences nearly the full tidal range inundation. The backshore area is backed by what appears to be a stabilized manmade berm (likely riprap or log bulkhead) intended to minimize flooding during high tides. The berm also limits sediment exchange, large wood movement, and wave overtopping during storms at high tide. The sediment characteristics on the beach are relatively uniform, with the backshore area above OHWM composed primarily of sand (Sediment Point 29) and the foreshore composed of a mixture of sand and gravel that varies with the wave, tide, and elevation (see Sediment Point 30). The size of the material on the beach is consistent with beach sediment located to the south, though appears slightly finer near the creek mouth. Sand more readily deposits near the creek mouth due to sheltering from waves and net northerly sediment drift being detained by the riprap stabilized creek mouth that extends into the foreshore zone. At the lowest portion of the foreshore area (~EL 3.5 feet NAVD88), the beach slope abruptly flattens and sediments transition to a mixture of sand/silt/gravel typical of low tide terraces in Puget Sound, but with a high percentage of gravel due to the presence of the nearby creek delta.

Figure 6. Variable sediment distribution on beach profile at South Shoreline (facing east)

3.3.3. Delta

This portion of the project site is located near and offshore of the creek mouth, and below the abrupt break in slope in the lower foreshore that marks the change from high tide beach to low tide terrace. Sediments on the delta vary, but are typified by Sediment Point 5, with relatively large gravel over and interbedded with mixed sand/silt. The delta sediments are exposed to strong wind-wave action, as evidenced by the complex pattern of shoals and relatively large size of materials present at the surface of the delta. Portions of the delta to the north of the creek mouth were primarily coarse gravel/cobble pavement, over silt/sand and can be seen in Sediment Point 7. The most seaward portions of the delta and areas near the south delta edge were covered with algae and composed of sediment containing a higher percentage of silt and sand when compared to the delta shoals near the creek mouth. It was observed that a broken up asphalt ramp exists along the south margin of the delta; likely portions of a relic boat ramp long abandoned. Historical aerial photos from the early 1950s depict a boat ramp in operation along the southern boundary of the park. CHE marked the locations of the structure with GPS equipment, but its precise position and size is obscured by sediment and deterioration.

3.3.4. Reference Beaches

Feeder bluffs immediately north of the project site are active and provide sediment to the nearshore zone. The lower part of the bluff stands nearly vertical and is composed of soils that are very dense and relatively resistant to erosion. Material deposited by bluff erosion likely originates from the upper bluff composed of glacial till and outwash materials more prone to landslide and instability. More information on site geology can be found in Shannon & Wilson (2015). Gravel and cobble size material derived from till and outwash are present on the beach. At high tide, such materials are redistributed by waves and currents, and are the likely the source of such materials observed in the lower intertidal zone north of the project area. LiDAR data indicate that beach slopes are relatively flat (15H:1V). Beach sediments appear similar to the south shoreline area of the project site, with a higher percentage of gravel due to the adjacency to the feeder bluffs. Beaches south of the project area appear the same as the south shoreline area. Refer to Appendix C for more information.

3.4. Suitable Forage Fish Substrate

To characterize the existing suitable substrate for forage fish, physical characteristics of the sediment and wave energy/exposure were considered. Because surf smelt and sand lance typically utilize different substrates, they are addressed separately. Other factors, such as the complete lack of riparian vegetation and shade in the upper intertidal zone, are not considered but are known to be important for forage fish egg viability (Penttila 2007).

3.4.1. Surf Smelt

Surf smelt spawn in the upper intertidal zone, generally above +7 feet MLLW (approximately 4.5 feet NAVD88). Surf smelt prefer mixed sand and gravel beaches for spawning, with sediment between 1-7mm diameter range (Penttila 2007). Suitable elevations and substrate are present in the south shoreline area to support surf smelt spawning and spawning has been observed by WDFW in 1995. Narrow patches of highly mobile suitable sediment do exist along portions of the north shoreline area; however, the elevations of these patches are too low and they are too dynamic for suitable spawning. The delta area is too coarse and low to support spawning, in general.

3.4.2. Sand Lance

Sand lance spawn in upper intertidal zone, generally above +5 feet MLLW (approximately 2.5 feet NAVD88). Sand lance prefer small substrates for spawning, primarily consisting of sand from 0.2-0.4 mm diameter range (Penttila 2007). Suitable elevations and substrate are present in the south shoreline area in the upper intertidal zone to support sand lance spawning, though sediments are on the coarse end of the preferred range. Sand lance spawning was observed in 2006 immediately south of the project area, where sediments appear similar to the south shoreline area. Again, small patches of highly mobile fine sediment do exist along portions of the north shoreline area; however, the elevations of these patches are too low and non-contiguous to provide suitable spawning habitat for sand lance. The delta area is too coarse to support sand lance spawning.

3.5. Existing Rock and Fill

During the site visit on August 11, 2015, CHE engineers visually evaluated the condition and quality of rock present in the existing revetment and groin features.

Rocks forming the revetment and groin are primarily basalt, though other types of rock are also present. Overall, it appears that approximately 70% of the remaining rocks on the revetment are in fair condition and may be suitable for reuse onsite as revetments or rockery walls if required for the project, pending further analysis. Because rocks have been exposed to the elements since 1952, the remaining service life of reused rock would be limited. Approximately 30% of the rocks are either highly weathered, cracked, or exhibit signs of deterioration and would not be suitable for reuse in the uplands; however, rocks larger than 1 foot in size may be suitable for reuse to improve nearby diving reef substrate. As rocks forming the revetment continue to naturally deteriorate, increased maintenance and repairs should be anticipated. The precise lifespan of the existing revetment has not been determined at this time; however, this should be evaluated as part of the no action alternative because portions of the revetment show signs of deterioration, undermining due to overtopping and freshwater runoff, and local slope failures caused by strong wave events at high tide.

Shannon & Wilson (2015) document test pits conducted to characterize the soil and fill material behind the rock revetment. The test pits indicate grain size results ranging from clean sand and gravel to silty sand. Overall, the materials encountered were visually consistent with native bluff material that was excavated and placed on the beach in 1952 to realign the creek and create uplands in front of the existing bluffs. Fill materials differ from native beach sediments due to the natural sorting of the sediments by waves and currents that occurs over time.

It may be feasible to reuse a portion of the remaining native bluff fill materials as beach nourishment to supplement feeder bluff activity that has been absent at the park since 1952. This might include segregating the most suitable materials (sand/gravel) during excavation and either placement in the upper intertidal zone for natural redistribution of sediment at high tide, or controlled placement on the foreshore when clean sands and gravels are available. The precise quantities, methods, and location of placement would be determined during feasibility and conceptual design.

3.6. Littoral Drift

CHE conducted analysis to estimate the dominant direction of wave energy and littoral drift at Saltwater State Park. The Coastal Atlas is a tool developed by Washington State Ecology (accessed September 2015) to make relevant information available for use in coastal and shoreline resource planning and management make estimates of direction of littoral drift by drift cell, and also categorize coastal landforms. Figure 7 shows wave fetch lengths (left panel) littoral drift direction (middle panel) and coastal landforms (right panel). The project site is located in an area where net littoral drift was estimated to be directed to the north (as indicated by the orange line and arrow), but located just north of a zone of diverging drift direction (in black). A 1991 Washington Ecology report (Schwartz *et al.* 1991) indicates two separate drift cells at the site, separated by the armor rock groin at the creek. According to the Coastal Atlas, a feeder bluff is located to the south of the site, as shown in the right panel of Figure 7. Based on the location of this bluff, it appears to feed both sediment drifting north and south.

Johannessen (2005) conducted an inventory and assessment of the beach in this drift cell (KI-8-3). The study found that a 66.3% loss of the original sediment sources has occurred compared with historic conditions. An accretion shoreform is located within and next to the project site, south of the groin. The accretion shoreform length was measured to be 760 feet in length.

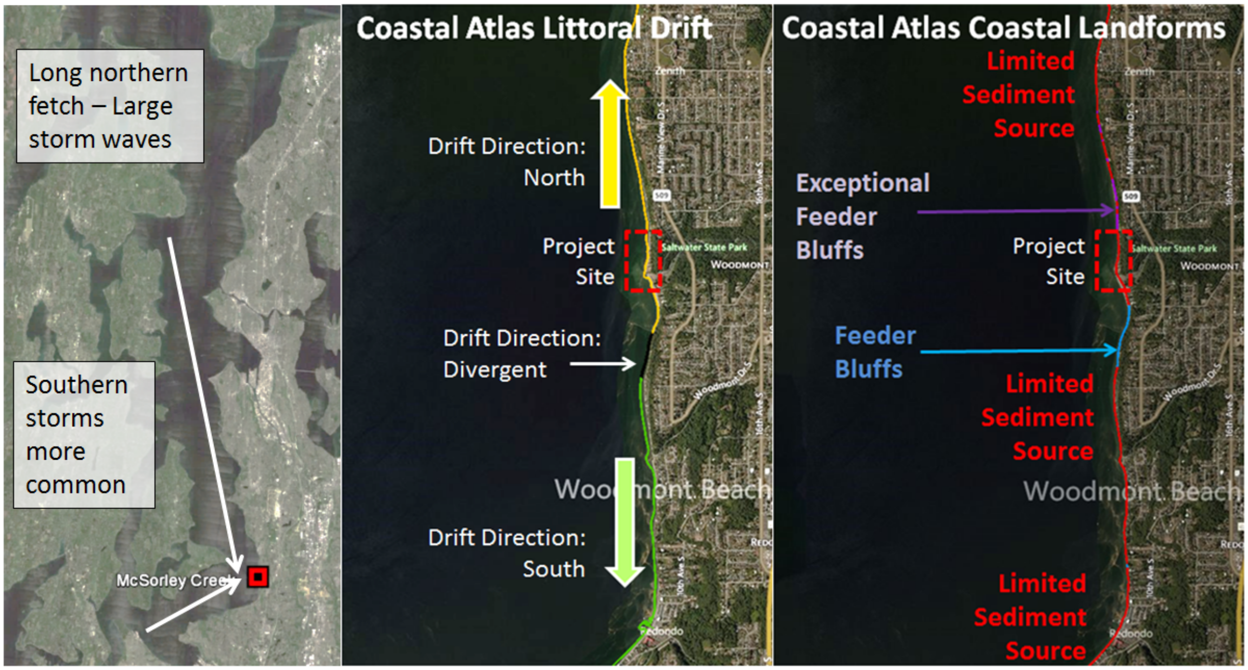

Figure 7. Puget Sound Coastal Atlas littoral drift and coastal landforms

CHE conducted wave modeling at the site in order to characterize the dominant direction of wave energy at the site. In lieu of wave data, CHE developed a numerical wave model using an industry-standard third-generation wave modeling tool, SWAN (Booij, *et al.* 1999), in order to estimate wind-wave conditions at the site. The computational grid is located in Appendix D. In order to determine wave model inputs CHE performed statistical analysis of the wind record located at West Point in Seattle, which is representative of the north/south wind wave generation in Puget Sound. The wind rose for data for West Point and Point Robinson is shown in Figure 1. In preliminary design, overlapping data between to the two stations (1984 to 1990) will be analyzed during known storm conditions to evaluate if local adjustments to the wind data at West Point are needed.

The wind rose at West Point shows that winds out of the north and south dominate for wind-wave growth in this area. Winds from the south are slightly more common (52% to 48%), and the wave fetch (distance over water the wind blows) is larger from the north and capable of generating large waves. CHE conducted an extremal wind analysis in order to estimate storm waves from various directions. The storm waves were generated using the SWAN model. Wave model results for a 2-year return wind-wave storm were extracted from a location approximately 350 feet offshore of the riprap at the mouth of the creek, and are shown in Table 2. Example model results are located in Appendix D. Though wind speeds are greatest out of the south, wave heights from the north are largest due to the longer fetch distance. Extreme north winds are typically associated with low pressure cold fronts which can occur for a longer duration over multiple tide cycles resulting in higher risk of damage.

Table 2. Two-Year Return Period Wind-Storm Wave Model Results

Return Period (yrs)	Wind Speed (kts)	Wind Direction (° TN)	Wave Height Hs (ft)	Wave Period T_p (s)	Wave Direction Θ_p (° TN)	Water Depth (ft, MLLW)
2	37	180 (S)	2.9	3.8	248	12
2	19	240 (SW)	1.9	3.1	236	12
2	26	350 (N)	3.1	4.7	312	12

Using the SWAN wave model, CHE developed a relationship between north and south wind direction/speed and wave conditions at the project site. Based on these relationships CHE estimated the long-term wave conditions near the site, and estimated the magnitude and direction of wave energy, using the wave energy flux method. Between 1984 and 2014, 54% of the wave energy was directed out of the south (driving sediment to the north), and 46% out of the north (driving sediment to the south). Year by year, however, the dominant wave energy direction may vary. For example in 2002 the energy out of the south (driving sediment north) was 47% of gross energy, and in 1989 it was 56%.

Based on this assessment, CHE estimates long-term sediment transport is directed northward at the project, consistent with the Coastal Atlas findings and Johannessen (2005). Though larger storm waves can be generated out of the north, storm wind-waves out of the south typically are more frequent. These opposing forcing mechanisms result in a weak overall signal and may vary year-to-year.

This assessment of net northerly drift is validated by field indicators, which include the accreting beach south of the creek mouth and delta. If net sediment transport direction were north-to-south, the beach area would likely erode due to lack of source.

3.7. Coastal Processes Discussion

Coastal processes at the project site have been affected in part by shoreline modifications. Sediment sources at the project site are limited as indicated by the Coastal Atlas figure (Figure 7), due to the armoring and development along the bluff, and as described in Johannessen (2005). However, sediment is still accumulating south of the armor rock groin structure at the creek and is fed by the feeder bluff located to the south of the project site, as shown in Figure 8. Comparison of the beach to conditions in 1957 indicates approximately 70 feet of accretion between 1957 and 2013. This would be equivalent to an accretion rate of approximately 1 foot per year. In its present condition, a portion of the northward directed sediment may bypass the armor structure. Assuming a wedge shape beach accumulation pattern retained by the groin, (plan view) and a similar beach slope occurred in 1957 as occurs presently (~8H:1V), conceptual level calculations show an approximate accumulation rate along the 760-foot shore form of 100-175 CY per year (average of 0.13-0.20 CY per linear foot). Total feed rate may be greater due to sediment bypass at the groin.

According to Johannessen (2005), the accretionary beach created by the placement of the armor rock structure shown in Figure 8 extends 760 feet south, which includes private lands. Full removal of the revetment may result in net changes to the beach, which would likely cause the beach to migrate landward.

At the north end of the site the project is bordered by feeder bluffs, which are similar to the historic bluff conditions. The natural state of the lower part of these bluffs stands nearly vertical and is composed of soils that are very dense and relatively resistant to erosion. Full removal of the riprap on the project site will expose the bluff toe, and will be more susceptible to erosion and slope failure. Shannon and Wilson (2015) notes that following the removal of colluvium that now covers the in-place glacial soils on the lower slope, it is then likely that the upper bluff soils could be undermined, leading to instability on the upper bluff.

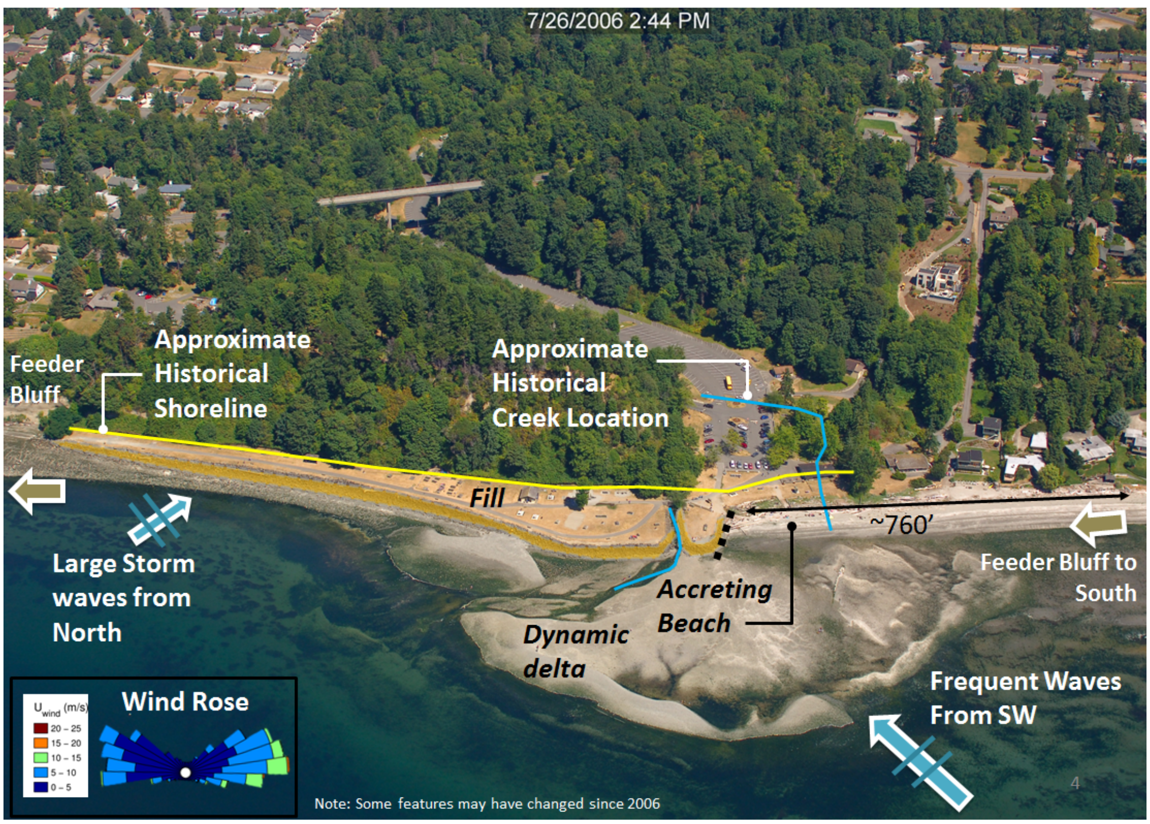

Figure 8. Coastal process summary and field indicators

4. Evaluation of Predicted Climate Change Impacts (Task 206)

CHE mapped potential sea-level rise scenarios outlined in the project scope (+1ft, +3ft and +5ft) relative to existing king tide conditions. In lieu of recent tide records at the project site, CHE obtained annual maximum tides at the Seattle tide station from 1983-2014, and compared these with 2-year return period tide statistics developed by NOAA for existing conditions in 2015. Based on this comparison, the NOAA 2-year tide statistic computed at the Seattle station was determined to be representative of typical king tides at the Seattle station. The comparison of the 2-year tide statistic to 31 years of annual maximum water surface elevation data is shown in Figure 9. This figure shows the maximum water surface elevation varies year-to-year, and accordingly future high tide elevations should be expected to have similar variability on the order of 1-2 feet.

In order to transform the 2-year tide statistic from the Seattle station to the project site, 0.18 feet of tide elevation was added to account for astronomical tidal height differences, based on comparison of tidal datums at Seattle and the project site using the NOAA tool, VDatum. The plot in Appendix C does not imply hydraulic connectivity, and is based on elevations only. Note also that this analysis is not predictive or intended to represent any specific climate change scenario. Rather, this serves as a parametric analysis of three potential sea level rise heights that may or may not occur in the future. Effects of possibly higher wave heights associated with extreme storms are not accounted for.

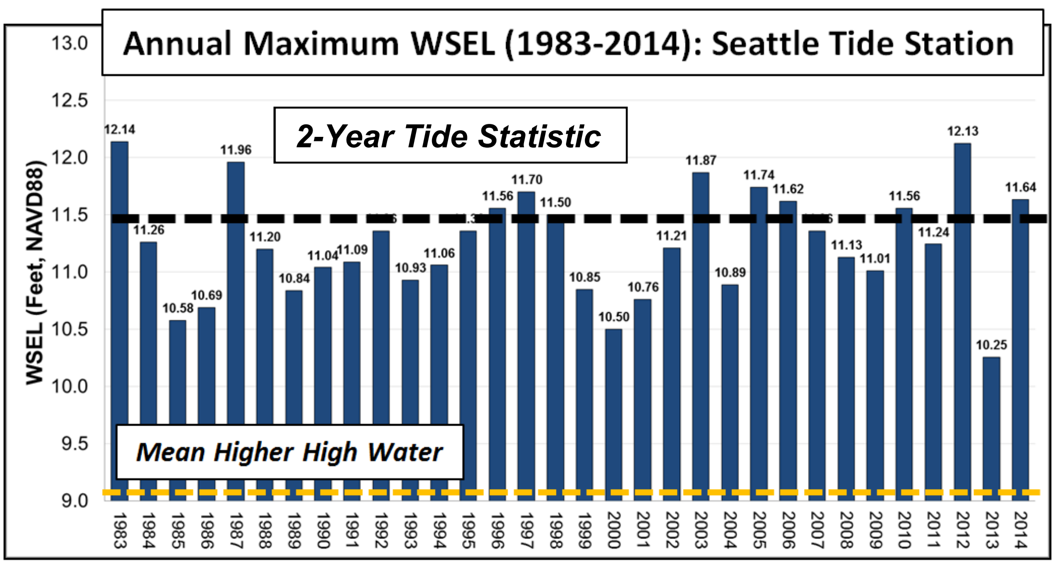

Figure 9. Annual maximum high tide (NOAA Station ID: 9447130)

Appendix E figure depicts various sea level rise scenario plots for the project site area. Note that extreme high tides will exceed the king tide level used in this evaluation, per Figure 9.

5. Summary of Key Findings

In accordance with Scope Tasks 204, 205 and 206, CHE has reviewed existing data, conducted a preliminary assessment on shoreline geomorphic processes, and provided a parametric analysis of potential sea level rise scenarios (+1, +3, +5 ft). Based on these tasks, CHE has developed the following key findings:

5.1. Data

- King Country-provided nearshore LiDAR bathymetric data was superseded in the project base map by LiDAR data sourced from the publically available PSLC and the survey conducted by Alliance-1 in August 2015.
- A historical aerial photo from 1936 contains distortions and has limited physical reference points; therefore, shoreline and creek change estimates are approximate.

5.2. Shoreline Modifications

- Review of project construction drawings indicates a portion of the bluff located north of McSorley Creek was excavated in 1952. After excavation, the McSorley Creek mouth was re-located to a newly constructed riprapped creek bed approximately 175 feet north of the natural location, in the previous location of the excavated bluff.
- Excavated bluff material was used as fill behind the revetment in order to move the shoreline seaward approximately 180 feet at the new creek mouth. The fill was stabilized with approximately 700 CY of riprap along the new creek and 8,180 tons of riprap along the shoreline on the revetment and groin, according to project drawings.

5.3. Shoreline Processes

- CHE estimates the long-term sediment transport is directed northward at the project, consistent with the Washington Coastal Atlas findings. However, net northerly drift appears weak and actual drift direction may vary year-to-year due to variable meteorological conditions.
- North of the McSorley Creek delta, waves approach the riprap revetment from relatively deep water and more directly; thus, leading to higher wave energy reaching this area.
- The site is relatively exposed to wave energy from the north due to long fetch and shoreline orientation. Large and long duration storm waves can be expected and must be factored into the design of restoration concepts.
- The beach south of the creek mouth presently provides suitable forage fish spawning substrate, energy, and elevations. Suitable forage fish spawning locations are otherwise not available on site.
- Subsequent project phases must take into consideration the potential effects of groin and creek mouth modifications on both updrift and downdrift shorelines.

- Coastal and geomorphic processes should be considered in later phases of the design in parallel, considering the natural state of the bluffs on-site are feeder bluffs.
- In order to protect lands above the bluffs at the project site, bluff toe protection should be provided in areas where protection is required by project criteria.
- Fill materials differ from beach sediments due to the natural sorting of the sediments by waves and currents that occurs. It may be feasible to reuse a portion of the remaining native bluff fill materials as beach nourishment to supplement feeder bluff activity that has been absent at the park since 1952. Fill materials may also be suitable for reuse in the uplands to raise grades, in accordance with the geotechnical recommendations in Shannon & Wilson (2015).
- The existing shoreline area south of the creek has accreted seaward approximately 70 feet since 1952 construction due to net south-to-north littoral drift and the effect of the rock groin which retains sediment. Modification of the groin (partial or full removal) would likely result in landward directed adjustment to the beach (erosion) within the area south of the creek mouth; therefore, a detailed assessment during design will be required.
- Existing beach around creek mouth appears to have reached a new equilibrium and any proposed modifications need to be analyzed to assess the change to any restoration concept or existing habitat areas (i.e., forage fish beach).

5.4. Sea-Level Rise

- Nearshore low lying areas will be subject to more frequent flooding in the short-term and should be considered in planning type and location of any new infrastructure.

6. References

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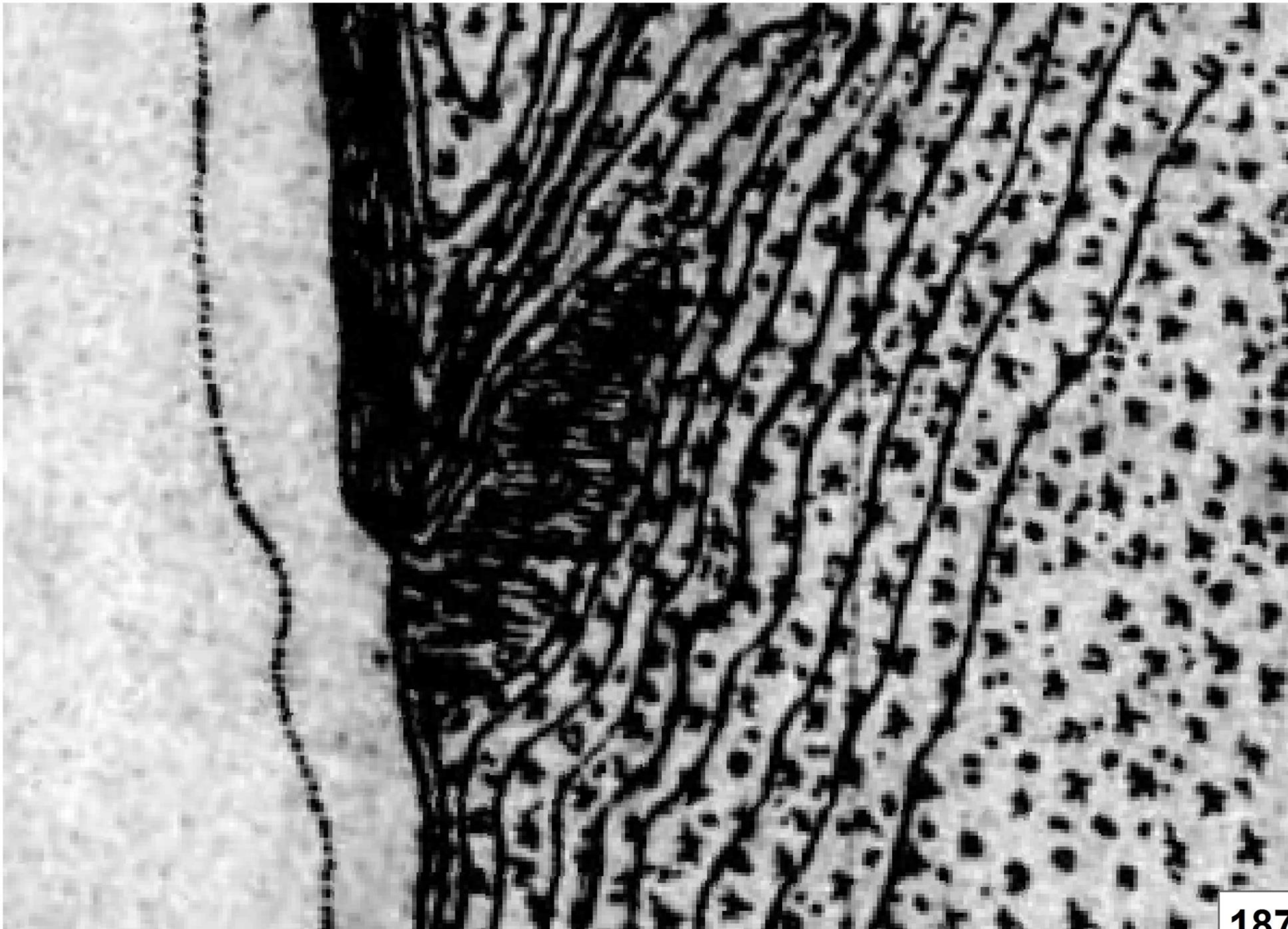
APPENDIX A

Historical Charts and Maps (T-Sheet, 1936, 1957, 2012)



1877

1936


1957


2012

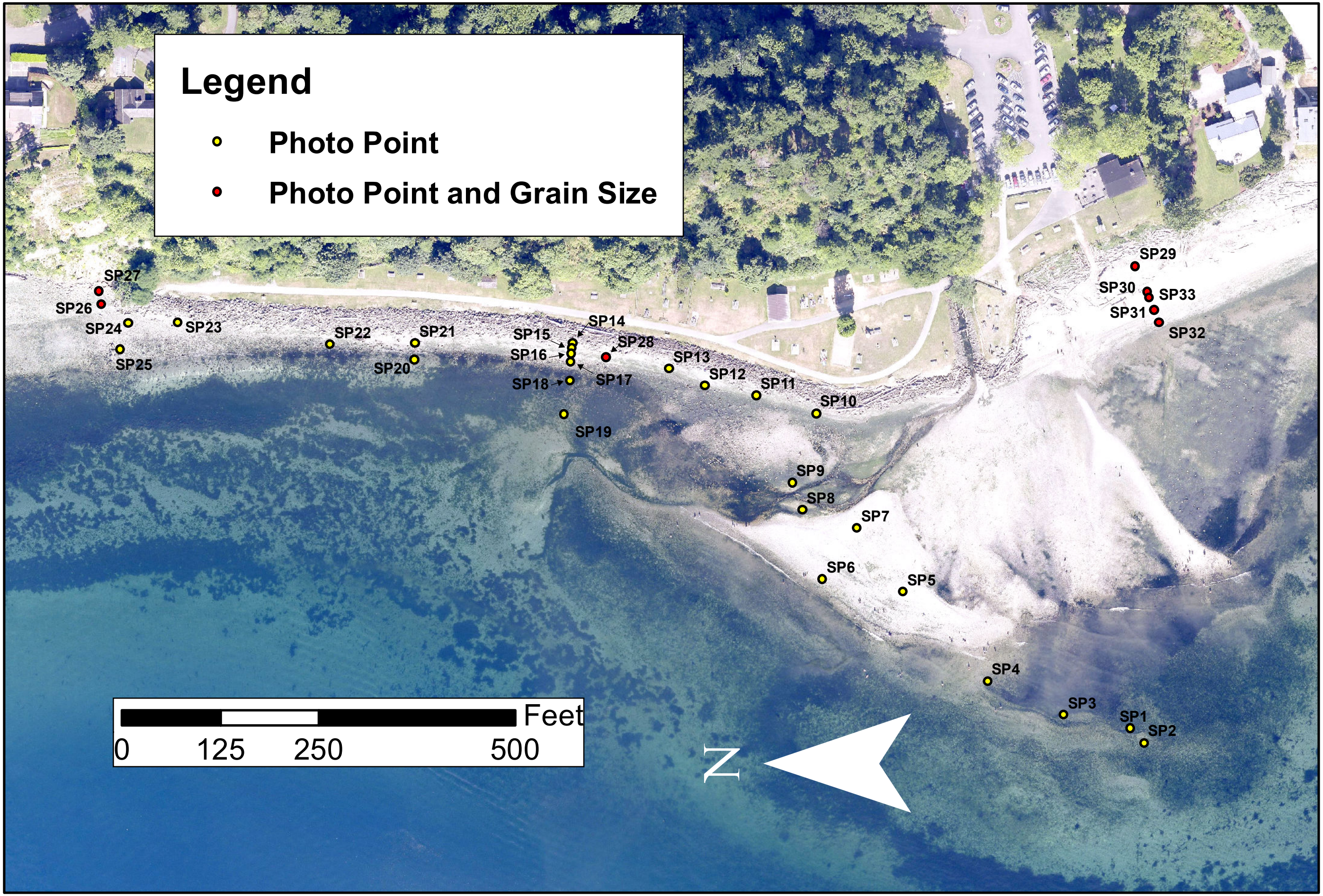
APPENDIX B

Surface Sediment Photos

McSorley Creek Pocket Estuary Restoration at Saltwater State Park
Sediment Survey Points

ID	Easting (ft)	Northing (ft)	Elev.(ft, NAVD88)	Date (m/dd/year)	Time (PST)
SP1	1270386.0	139381.4	-1.44	8/11/2015	7:41:25
SP2	1270367.2	139364.0	-1.72	8/11/2015	7:42:09
SP3	1270403.0	139465.9	-1.7	8/12/2015	7:45:45
SP4	1270445.8	139562.7	-0.64	8/13/2015	7:48:02
SP5	1270559.6	139670.0	2.62	8/14/2015	7:50:05
SP6	1270575.5	139772.6	1.39	8/15/2015	7:52:21
SP7	1270640.3	139728.9	3.43	8/16/2015	7:58:49
SP8	1270663.2	139797.9	0.79	8/17/2015	8:02:55
SP9	1270697.9	139810.8	0.72	8/18/2015	8:03:51
SP10	1270786.2	139780.6	3.24	8/19/2015	8:07:18
SP11	1270809.2	139856.4	3.05	8/20/2015	8:09:41
SP12	1270821.6	139922.3	1.98	8/21/2015	8:12:42
SP13	1270843.0	139967.8	2.56	8/22/2015	8:14:29
SP14	1270875.4	140089.8	4.58	8/23/2015	8:17:02
SP15	1270869.0	140090.8	2.38	8/24/2015	8:18:04
SP16	1270862.6	140091.7	1.55	8/25/2015	8:18:39
SP17	1270851.3	140092.4	0.68	8/26/2015	8:20:32
SP18	1270827.4	140093.5	-0.87	8/27/2015	8:21:55
SP19	1270785.4	140100.8	-2.32	8/28/2015	8:22:52
SP20	1270854.8	140291.0	-1.05	8/29/2015	8:27:31
SP21	1270875.3	140290.6	1.03	8/30/2015	8:28:33
SP22	1270873.8	140398.2	0.56	8/31/2015	8:30:54
SP23	1270901.4	140591.7	3.49	9/1/2015	8:33:55
SP24	1270900.9	140654.5	3.68	9/2/2015	8:35:50
SP25	1270867.7	140665.0	1.36	9/3/2015	8:37:47
SP26	1270924.8	140688.7	6.06	9/4/2015	8:40:53
SP27	1270941.9	140691.4	7.97	9/5/2015	8:42:11
SP28	1270857.3	140047.4	1.87	9/6/2015	8:51:46
SP29	1270973.6	139375.0	10.58	9/7/2015	9:39:05
SP30	1270941.1	139359.5	8.79	9/8/2015	9:39:41
SP31	1270917.6	139351.5	5.57	9/9/2015	9:40:35
SP32	1270901.2	139344.8	3.57	9/10/2015	9:41:27
SP33	1270933.3	139357.1	7.83		9:44:28

NOTE: WA STATE PLANE NORTH, FT, NAD83



Legend
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Photo Point and Grain Size
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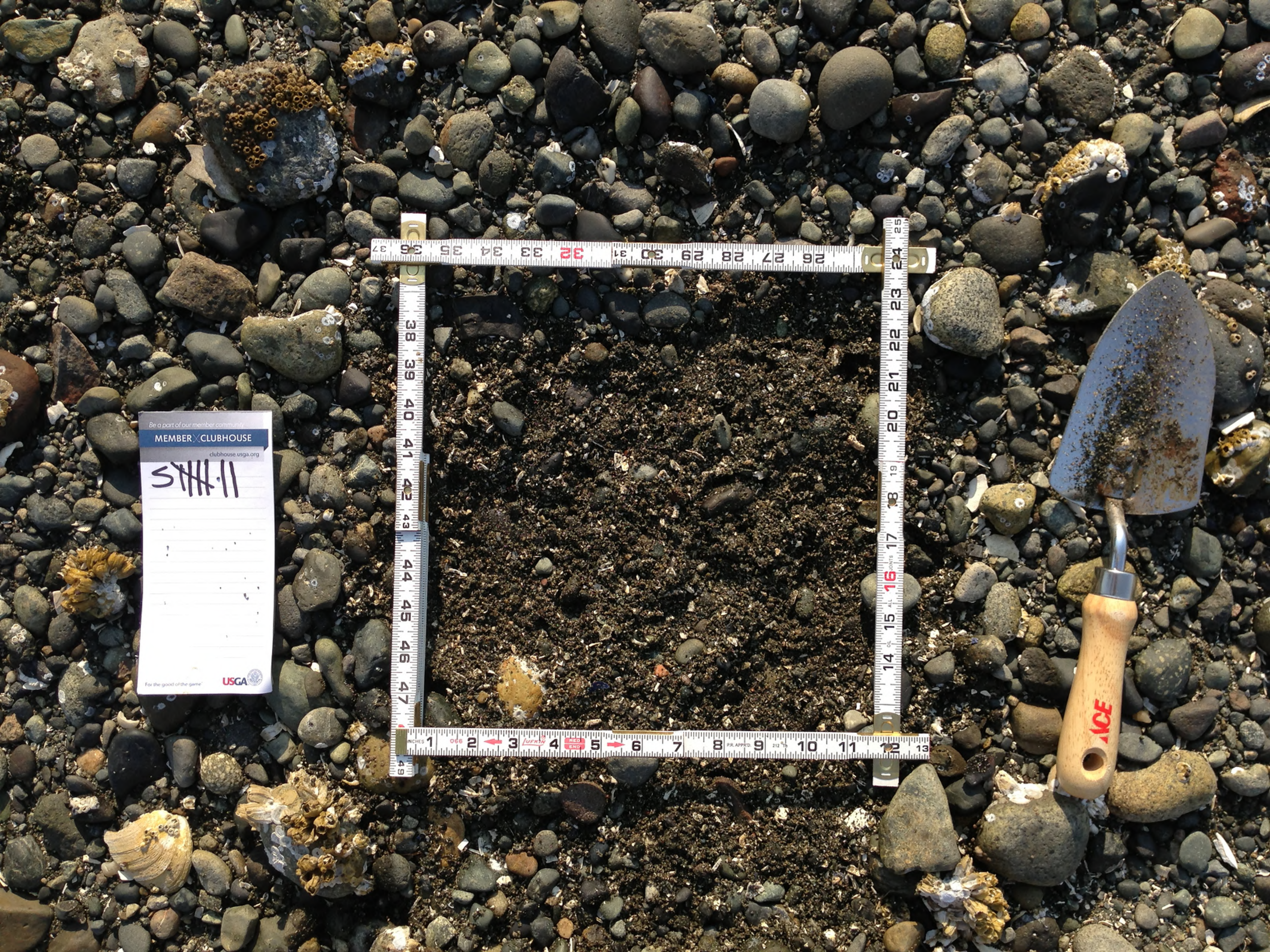
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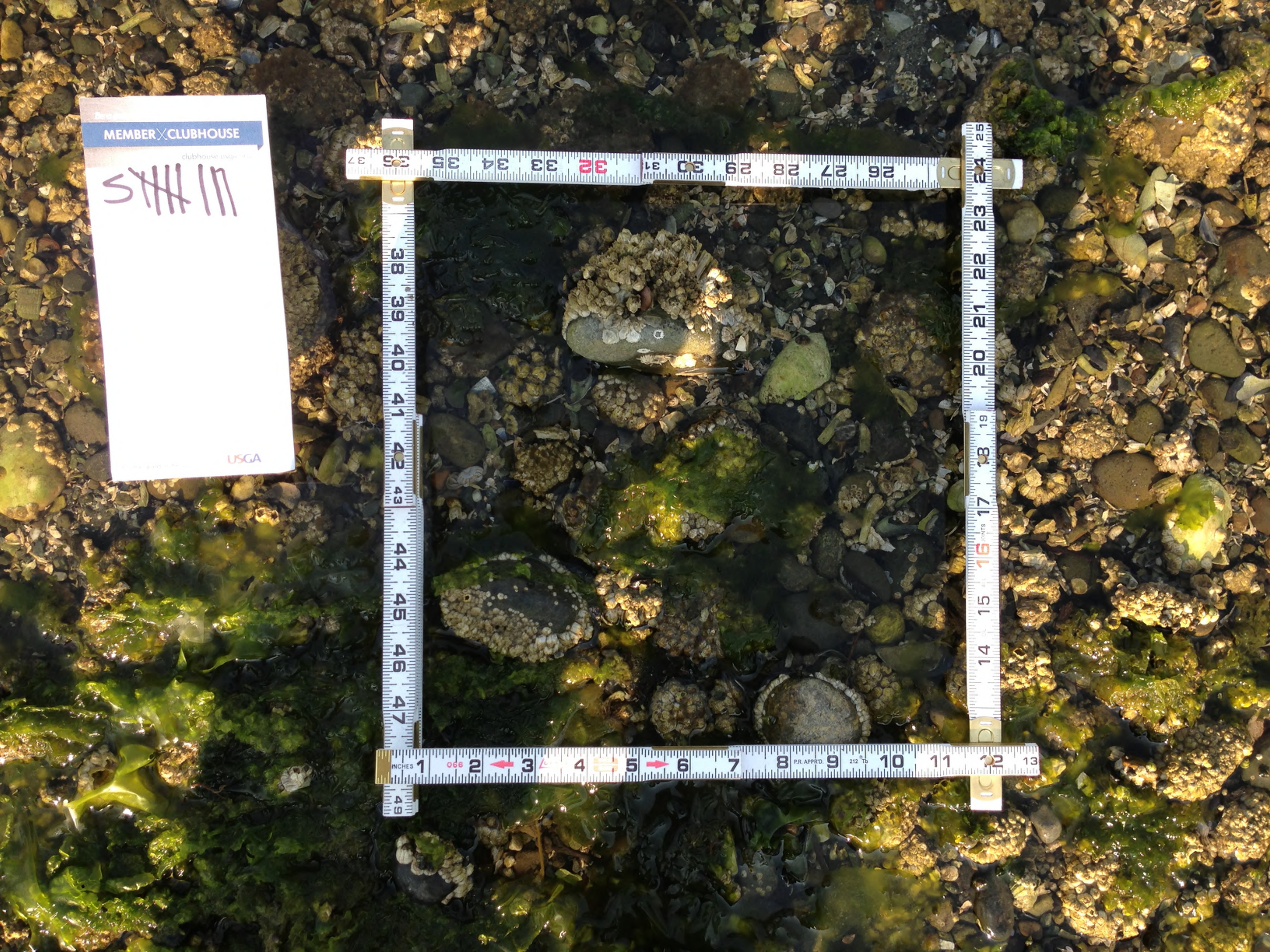
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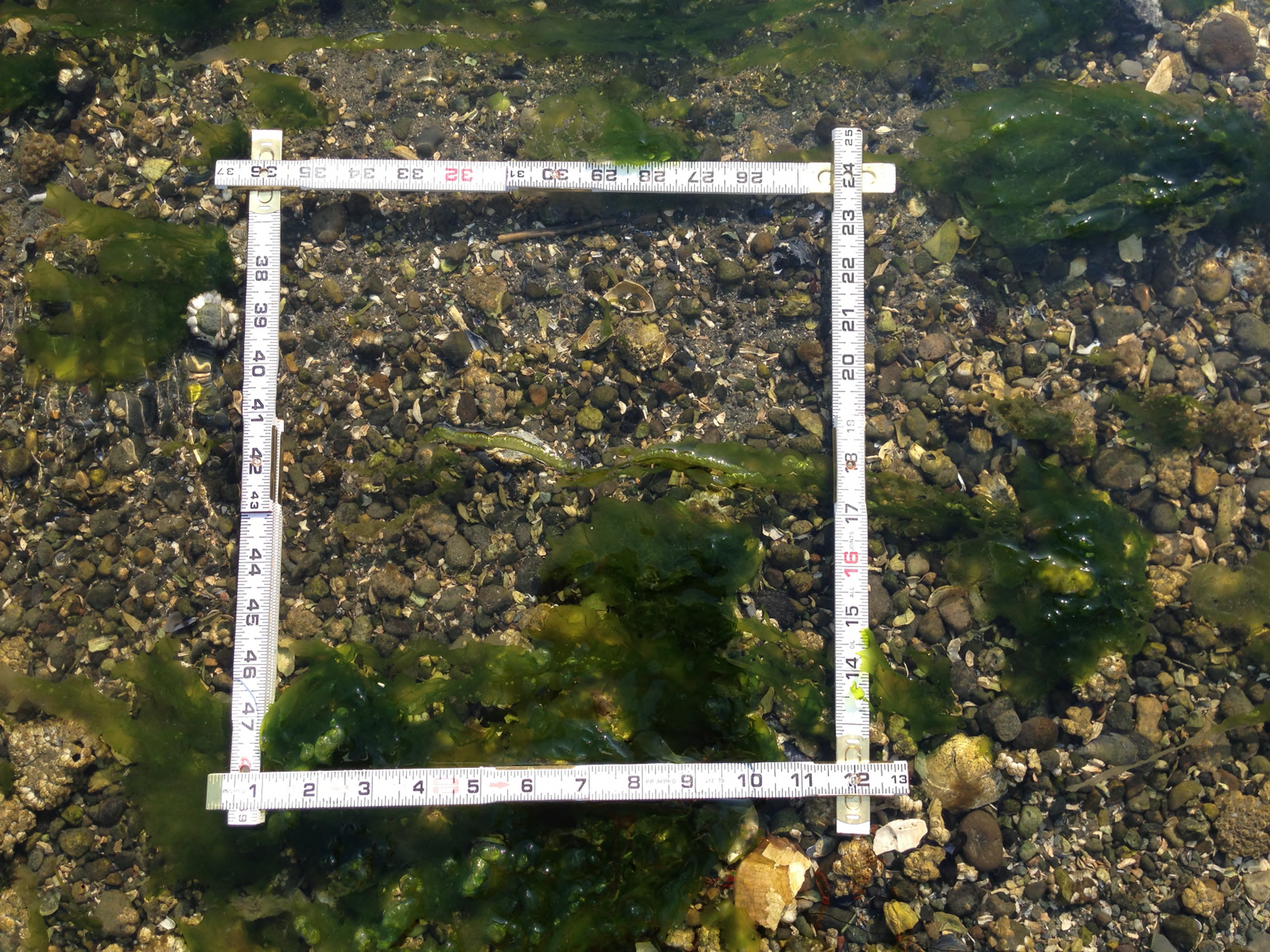


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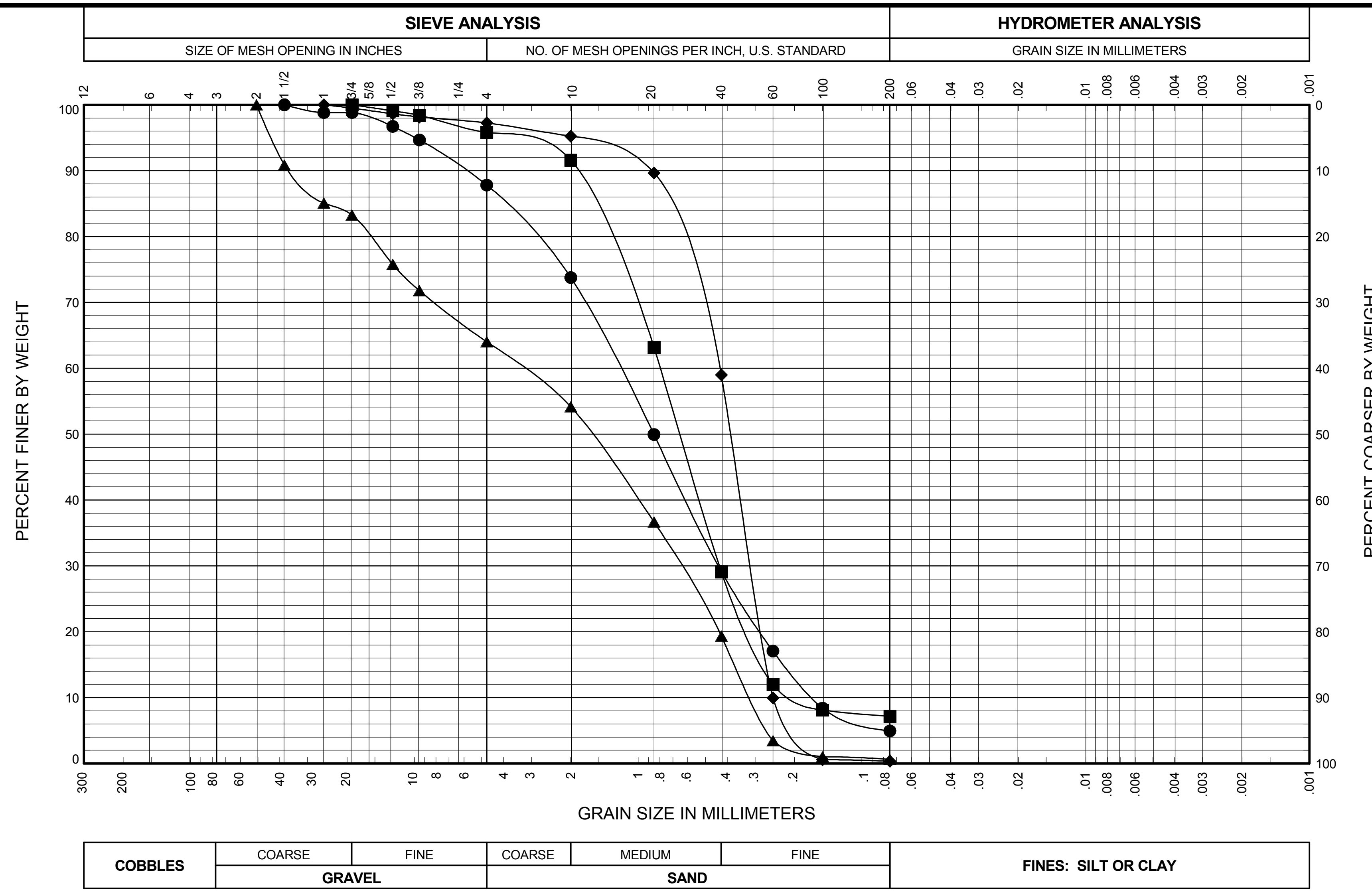
APPENDIX C

Grain Size Analysis (From Shannon & Wilson)



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	COBBLE %	GRAVEL %	SAND %	FINES %	NAT. W.C. %	TEST BY	REVIEW BY	ASTM STD
● Costal Engineers Sample 26	0.0	SW	Well-Graded Sand		12	83	4.9	16.1	AKV	AKV	D422
■ Costal Engineers Sample 27	0.0	SP-SM	Poorly Graded Sand with Silt		4	89	7.2	8.9	AKV	AKV	D422
▲ Costal Engineers Sample 28*	0.0	SP	Poorly Graded Sand with Gravel		36	63	0.6	5.8	AKV	AKV	D422
◆ Costal Engineers Sample 29	0.0	SP	Poorly Graded Sand		3	97	0.3	0.4	AKV	AKV	D422

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Des Moines, Washington

GRAIN SIZE DISTRIBUTION

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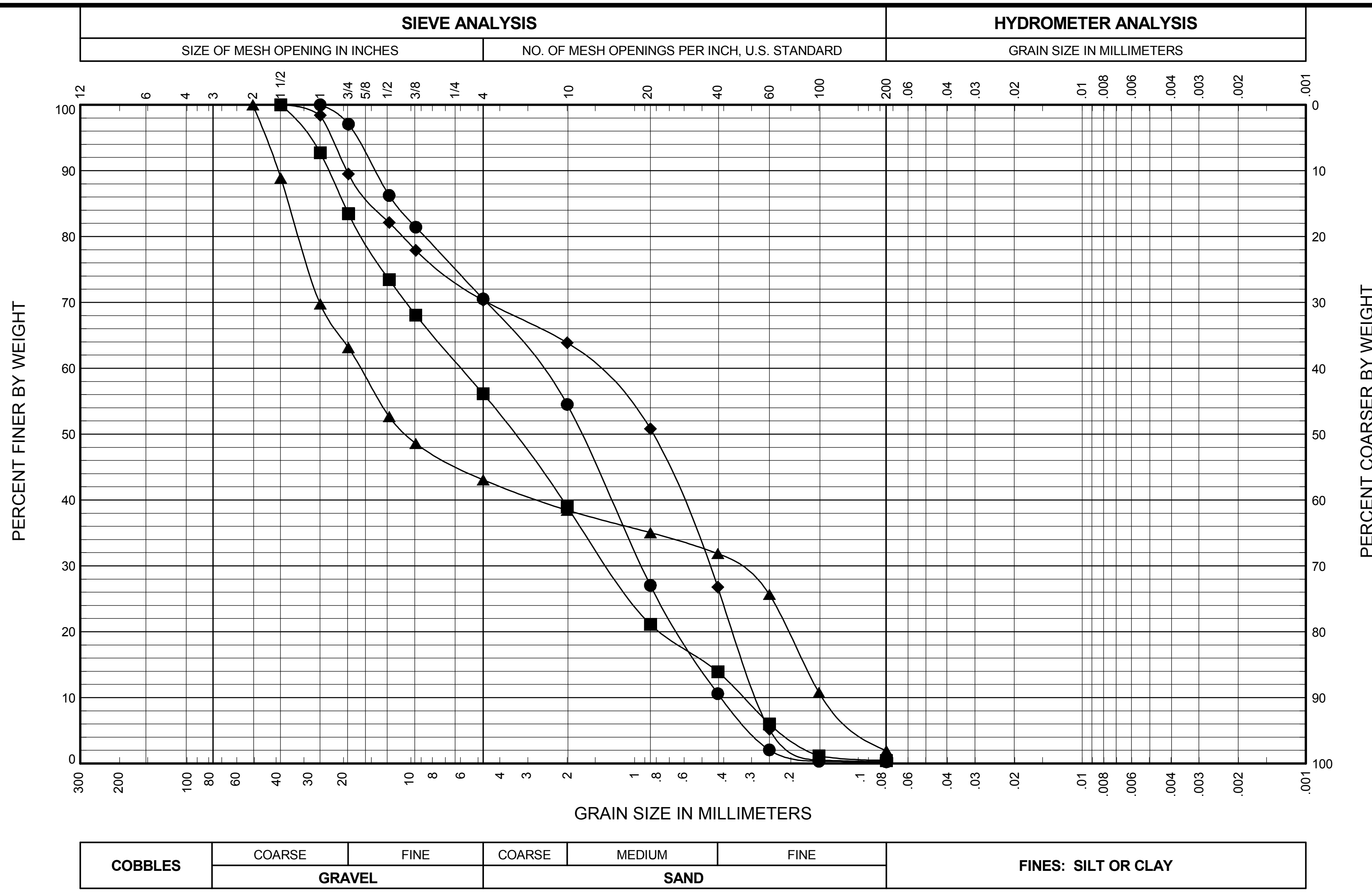
FIG. FINAL
Sheet 1 of 1

** Sample specimen weight did not meet required minimum mass for ASTM test method.*

FIG. FINAL

AASHTO GSA MAIN 21-22077.GPJ SHAN WIL.GDT 10/7/15

AASHTO GSA MAIN 21-22077.GPJ SHAN WIL.GDT 10/7/15



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	COBBLE %	GRAVEL %	SAND %	FINES %	NAT. W.C. %	TEST BY	REVIEW BY	ASTM STD
● Costal Engineers Sample 30	0.0	SP	Poorly Graded Sand with Gravel		29	70	0.2	1.2	AKV	AKV	D422
■ Costal Engineers Sample 31	0.0	SP	Poorly Graded Sand with Gravel		44	56	0.5	4.3	AKV	AKV	D422
▲ Costal Engineers Sample 32	0.0	GP	Poorly Graded Gravel with Sand		57	41	1.9	12.0	AKV	AKV	D422
◆ Costal Engineers Sample 33	0.0	SP	Poorly Graded Sand with Gravel		30	70	0.3	3.6	AKV	AKV	D422

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FIG. FINAL
Sheet 1 of 1

FIG. FINAL

APPENDIX D

Wave Modeling (Domain, 2-Year results from North and South)

Figure A.1 SWAN Model Domain Extents and Bathymetric Grid Data

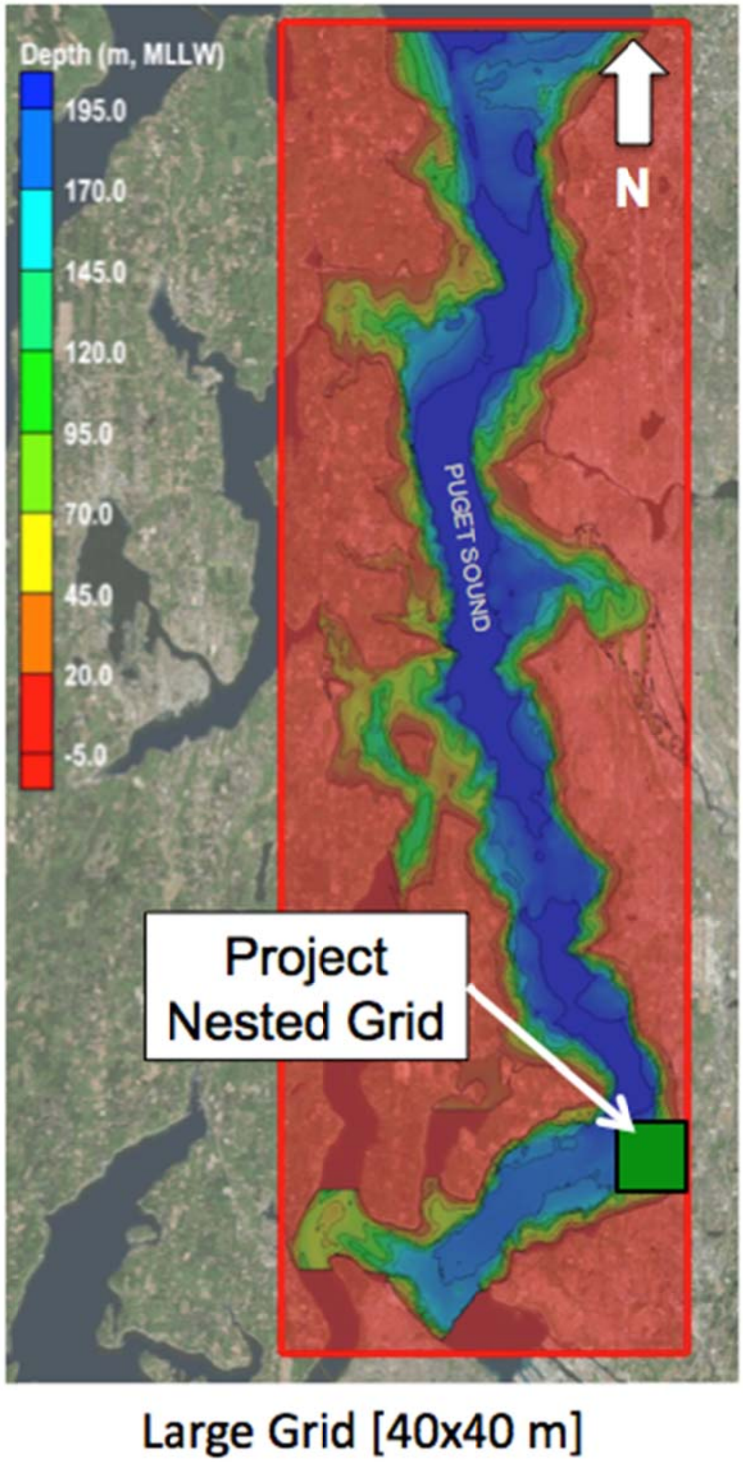
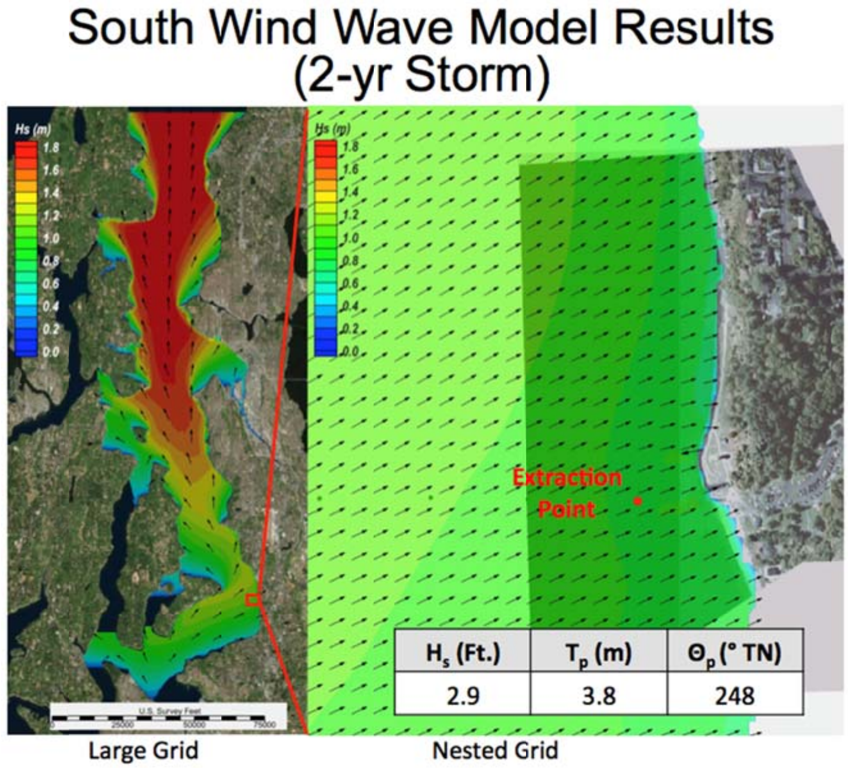
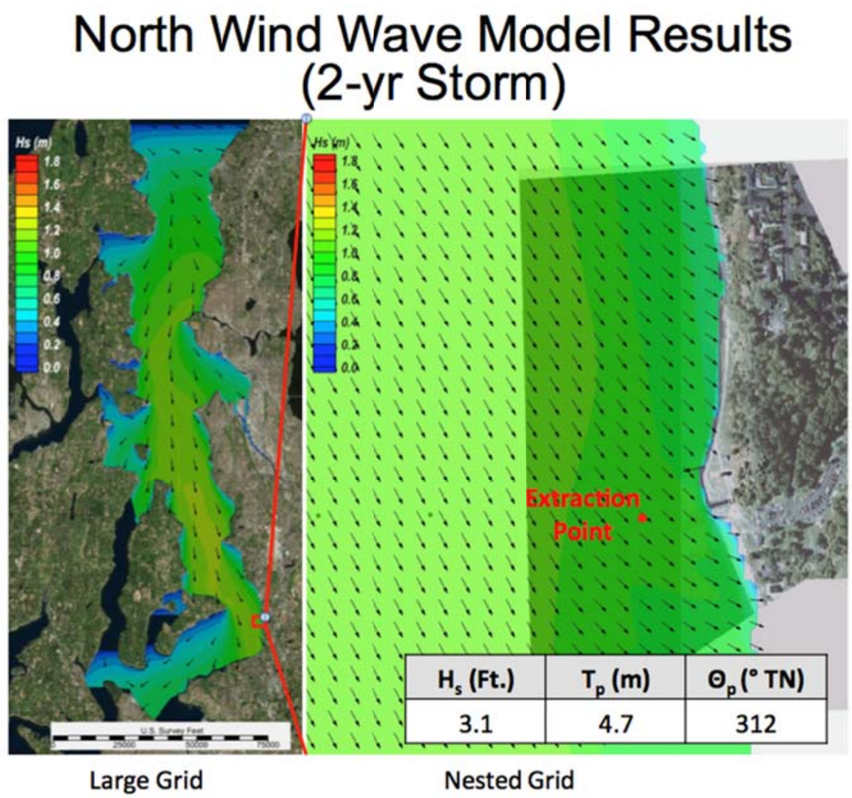


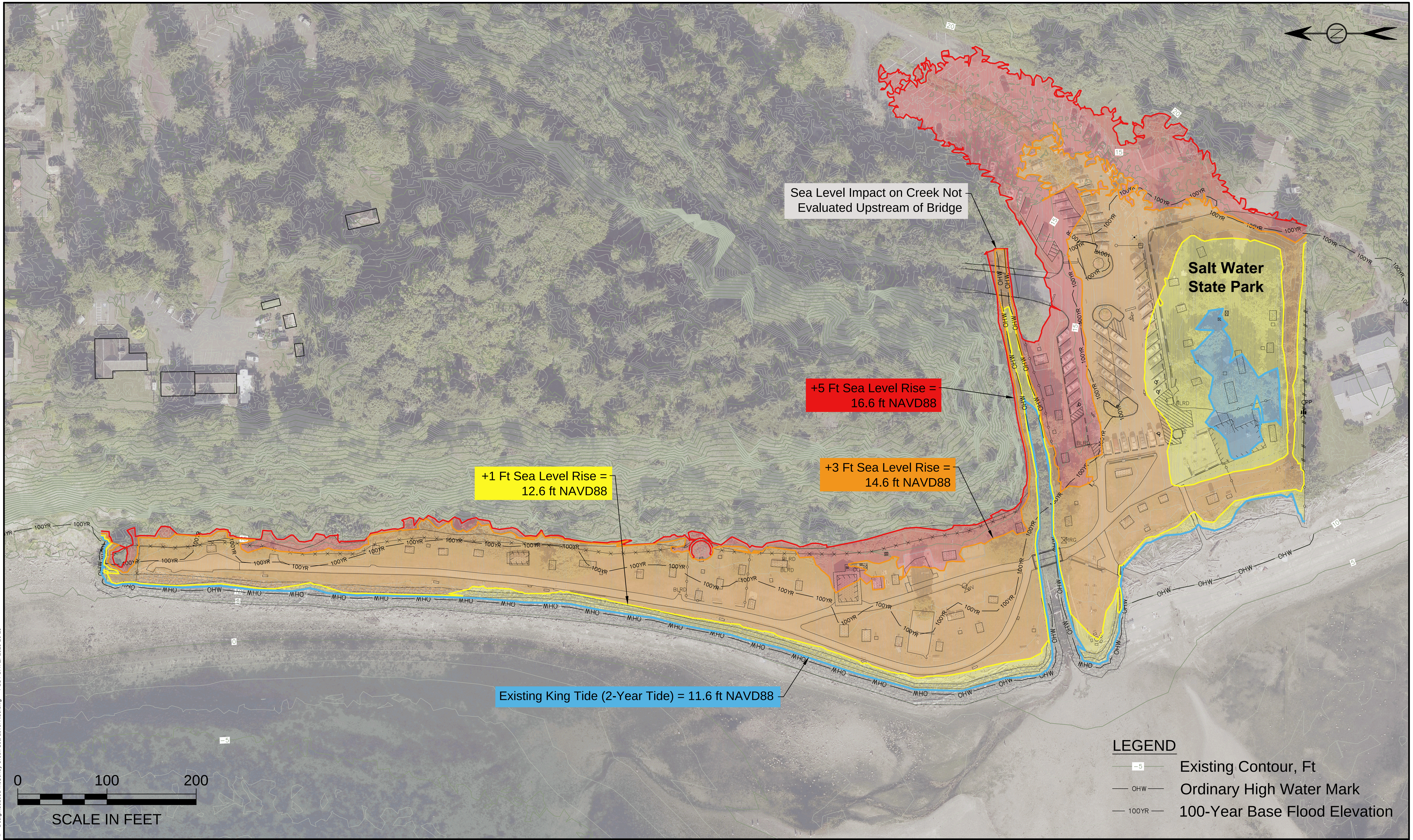
Figure A.2. SWAN Model Example Results





APPENDIX E

Sea Level Rise Plots



FILE: Z:\351681 McSorley Creek SPI7 - Design\351681-McSorley Creek Sea-Level Rise.dwg PLOT DATE: 2015-10-29

King County

McSorley Creek Pocket Estuary Restoration
Sea Level Rise Analysis

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